Appendix A

VENTILATION SIMULATION METHODOLOGY AND REQUIREMENTS

A1 General

The natural ventilation simulation shall be carried out using computational fluid dynamics (CFD) modelling to identify the most effective building design and layout for the development. The simulation results and recommendations derived are to be adopted to meet the intent of the criteria.

A2 General Ventilation Simulation Requirement

A2.1 Simulation Software

The CFD modelling shall be carried out using the well validated software. The CFD solver shall have the minimum capability of solving the Navier-Stokes fluid flow equations for a three-dimensional incompressible flow at steady state. Turbulence modelling shall also be included with the minimum requirement of using the standard k-ε turbulence model, coupled with the standard wall function. [Note: It is recommended to use the enhanced RANS eddy viscosity model (apart from the minimum realizable k-ε turbulence model) and RANS Reynolds Stress Model.]

A2.2 Conditions

All simulation models shall be carried out under isothermal conditions at steady state condition. If the impact of heat sources is significant, heat source modelling shall be included. (Note: The aggregated heat load from heat dissipating devices shall be modelled. Boussinesq or variable density can be used.)

A2.2.1 Computational Domain and Surrounding Buildings

The computational domain shall include the development of interest and the far field boundary which should be located far enough from the building model to avoid artificial acceleration of the flow. As a general guideline, the direction blockage ratio (BR_L & BR_H) along lateral and vertical directions should be less than 17%.

$$BR_l = \frac{L_{\,Buildings}}{L_{Domain}} < 17\% \qquad BR_H = \frac{H_{\,Buildings,max}}{H_{Domain}} < 17\%$$

is also important to ensure that the blockage ratio (BR) arising from the projection of building frontal to the domain enclosure is no larger than 3%.

The surrounding buildings residing within 500 m distance from the edge of development of interest should be modelled explicitly. If the building and surrounding development are located within hilly terrain with elevation more than 10 m height, the topography information should also be included in the simulation models to capture the wind redistribution arising from terrain gradient and vicinity effect. The ground surface beyond surrounding buildings site can be modelled implicitly using the Davenport-Wieringa roughness classification

A2.2.2 Grid Size

The computational grid generated for all simulations shall resolve the salient flow features in the naturally ventilated spaces and around the development. The recommended grid sizes are as follows:

Location	Grid Size (m)
Within the functional spaces of interest	*0.1 – 0.5*
Building of interest	*0.5 – 1.0*
Surrounding building	*1.0 – 5.0*
From ground surface to 10m height in vertical direction	*0.5 – 1.0*
From 10m height to H_{max} height in vertical direction, (H_{max} is the height of the tallest building among the group of buildings modelled explicitly)	*1.0 – 5.0*

As a guide, the dimension of the computational elements is advised to follow the principles such as:

- Proper domain decomposition should be carried out to ensure a good quality mesh can be obtained.
- Hexahedra or prism body-fitted grid are preferred.
- A grid independent test shall be performed at the functional space through grid refinements in areas with sharp gradients.
- In terms of the computational cell quality, the skewness of the cell is advised no greater than 0.9.
- The maximum stretching ratio for near building cell size should be kept to be less than 1.4.

A2.2.3 Boundary Condition & Turbulence Modelling

a) <u>Inlet Atmospheric Boundary Condition</u>

Based on local climatic wind condition, meteorological data on the precise wind direction and velocity of the proposed site location for the month of December, March, June and September shall be used for the CFD simulation. The prevailing wind condition such as the mean speed and direction for Malaysia shall be taken from local prevailing wind data downloadable from GreenRE website. The inbound vertical wind profile shall assume to be given by the Logarithmic Law reference height at 15.0m

The aerodynamic roughness length z0 for wind profile should be selected from the updated Davenport-Wieringa roughness classification as follows, to match the terrain category of the development site of interest, including the tree/greenery effect.

z0 (m)	Landscape Description
0.0002 Sea	Open sea or lake (irrespective of the wave size), tidal flat, snow-covered flat plain, featureless desert, tarmac, concrete, with a free fetch of several kilometers
0.005 Smooth	Featureless land surface without any noticeable obstacles and with negligible vegetation; e.g. beaches, pack ice without large ridges, morass, and snow-covered or fallow open country.
0.03 Open	Level country with low vegetation (e.g. grass) and isolated obstacles with separations of at least 50 obstacle heights; e.g. grazing land without windbreaks, heather, moor and tundra, runway area of airports.
0.10 Roughly open	Cultivated area with regular cover of low crops, or moderately open country with occasional obstacles (e.g. low hedges, single rows of trees, isolated farms) at relative horizontal distances of at least 20 obstacle heights.
0.25 Rough	Recently-developed “young” landscape with high crops or crops of varying height, and scattered obstacles (e.g. dense shelterbelts, vineyards) at relative distances of about 15 obstacle heights.
0.50 Very rough	“Old” cultivated landscape with many rather large obstacle groups (large farms, clumps of forest) separated by open spaces of about 10 obstacle heights. Also low large vegetation with small interspaces such as bush land, orchards, young densely-planted forest.
1.0 Closed	Landscape totally and quite regularly covered with similar-size large obstacles, with open spaces comparable to the obstacle heights; e.g. mature regular forests, homogeneous cities or villages.

≥ 2.0 Chaotic	Centers of large towns with mixture of low-rise and high-rise buildings. Also irregular large forests with many clearings.

(b) Ground Surface

Using appropriate roughness parameters is an essential component for accurate simulation of Atmospheric Boundary Layer (ABL) flow. The two types of roughness parameters, (i) aerodynamic roughness length z_0 and (ii) equivalent sand- grain roughness height k_S, should be applied on different surface areas as listed:

Ground Surface Area	Roughness Parameter
Area 1: From domain Inlet boundary to the boundary of explicitly modelled buildings	Aerodynamic roughness length z_0
Area 2: Within the region of explicitly modelled buildings	Aerodynamic roughness length z_0
Area 3: Within the site boundary of the development of interest	Equivalent sand-grain roughness height k_S

The region of inlet, approach, and incident flow at the upstream of computational domain should be modelled with appropriate aerodynamics roughness length z_0 as well as the relationship between equivalent sand-grain roughness height kS with the corresponding aerodynamics roughness length z_0.

c) Top and Lateral Surface of Domain

Use zero velocity gradients and zero normal gradients, i.e. "symmetry" condition, for all variables at the top and lateral surface when the top and lateral boundaries of the domain are far away enough from the buildings (refer to the requirements on the domain size).

d) Outlet Surface of Domain

Use zero static pressure as the boundary condition at the outlet surface of computational domain.

A2.2.4 Discretization Schemes

In all circumstances, the users should attempt to apply 2nd order discretization schemes, which are preferred over 1st order discretization schemes to avoid numerical diffusion.

A2.2.5 Convergence Criteria

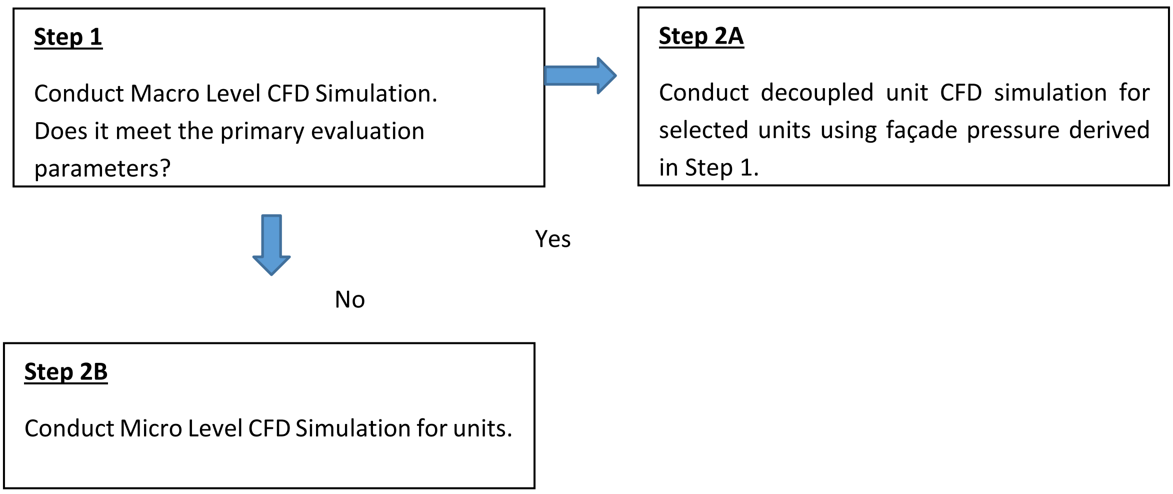
To ensure the changes in solution variables from one iteration to the next are negligible, residuals with at least 4 orders of magnitudes shall be achieved. In addition, monitoring points should be defined in the region of interest and the velocities at those points should be recorded to ensure that the flow has reached steady values when simulation is converged properly.

A3 Design Iteration

There shall be at least two iterations of simulation models to assess the wind flow conditions and air-flow pattern within the development to demonstrate the improvement in natural ventilation design. The simulation modelling can be conducted based on the two best prevailing wind directions for the building development.

B. Ventilation simulation for Residential Projects

This part is applicable for residential projects using CFD simulation and analysis. The simulation is recommended to be carried out with a steady temperature of 29.5^{o}C. The simulation results and the recommendations derived are to be implemented to ensure good natural ventilation. Simulation shall follow the methodology outlined in section 1.



Determine up to five (5) typical unit design layouts that have the majority number of units. If the proposed building development comprises less than 5 typical unit types, all the typical unit design layouts are to be selected for the simulation.

There shall be at least two iterations of simulation models to assess the wind flow conditions and air-flow pattern within the development to demonstrate the improvement in natural ventilation design. The simulation modelling can be conducted based on the two best prevailing wind directions for the building development.

3.1 Ventilation simulation modelling for pressure differential analysis

- Conduct a large-scale ventilation simulation modelling for development using the specified computational domain and grid stated to assess the wind flow conditions around the proposed building development and adjacent buildings. Natural ventilated corridor linked to the unit should be taken into consideration for the simulation models.

- From the simulation results, determine the wind pressure taken at 0.5 m from every assumed opening of all units at mid height level (capped at 20 story height) and the pressure difference (i.e. the difference of the maximum and minimum wind pressure) of each unit. In instances, where all or some of the typical unit layouts are not designed at mid-height level, the average wind pressure and respective pressure differences should be determined for these typical units located at the level closest to the mid-height level.

- Calculate the global pressure differential by summing all the pressure difference of all units divided by the total number of units (at mid height level).

- If the development level simulation result meets the primary evaluation parameters, the project would have deemed to satisfy the performance requirements to conduct a decoupled unit CFD simulation using the façade pressures derived.

Primary evaluation parameters:

- A minimum 60% of Dwelling Units with window openings facing the prevailing north or north-east and south or south-east directions AND a minimum 2.7 Pa of Global Pressure Differential of Dwelling Units located at building mid height level

  OR

- If < 60% of Dwelling Units with window openings facing the prevailing north or north-east and south or south-east directions, to meet a minimum 4.3 Pa of Global Pressure Differential of Dwelling Units located at building mid height level.

3.2 Step 2A Decoupled Ventilation simulation modelling for units

- Unit simulation to assess the air-flow patterns within all the five selected typical dwelling unit types. The façade wind pressure result taken from 3.1 shall be prescribed as the boundary condition. All living spaces in the dwelling unit are to be included in the modelling except for enclosed space, such as storeroom or CD shelter. All windows & doors are assumed to be fully opened as designed except for the main door which is assumed to be closed at all time unless a door gate or grille is provided by the developer.

- For residential buildings, the applicable areas refer to living room, open kitchen (which is connected to the living room), study rooms and all bedrooms. The area weighted average wind velocities of these areas are to be computed at horizontal plane 1.2 m above the floor level.
- The selected unit's area-weighted average wind velocity of the unit shall meet the prescribed performance in RES 1-2(a). The overall percentage of units achieving good natural ventilation is given by:

$$\frac{\sum(\text{No. of Selected Units for Each Layout x Area-Weighted Average Wind Velocity}}{\text{Total Number of Selected Units x 0.40 m/s}} \text{ x 100}$$

3.3 Step 2B Micro Level ventilation simulation modelling for units

- If the primary evaluation parameters were not achieved, from results of step 1 ventilation simulation for development, select the unit with pressure difference that is closest to the average pressure difference from each typical unit design layout. The maximum allowable margin of ± 10% difference from the average pressure difference is deemed acceptable.
- Conduct a large scale CFD simulation to assess the air flow conditions of these five (5) selected units. All living or functional spaces in the unit are to be included in the simulation modelling except for enclosed spaces such as storeroom or CD shelter. All windows & doors are assumed to be fully opened as designed except for the main door which is assumed to be closed at all time unless a door gate or grille is provided by the developer.
- From the simulation results, determine the area-weighted average wind velocity of each selected unit by considering the air flow conditions of the applicable areas. For residential buildings, the applicable areas refer to living room, open kitchen (which is connected to the living room), study rooms and all bedrooms. The area weighted average wind velocities of these areas are to be computed at horizontal plane 1.2 m above the floor level. The same applies to naturally ventilated functional spaces for non-residential buildings.
- The selected unit is deemed to have good natural ventilation if the area-weighted average wind velocity of the unit is not less than 0.4 m/s. The overall percentage of units achieving good natural ventilation is given by:

$$\frac{\sum(\text{No. of Selected Units for Each Layout x Area-Weighted Average Wind Velocity}}{\text{Total Number of Selected Units x 0.40 m/s}} \text{ x 100}$$

4.0 Thermal Comfort Simulation Methodology and Requirements

The thermal comfort assessment, where required, shall be carried out using Predicted Mean Vote (PMV) equation to identify the most effective building design and layout for the development. The assessment and simulation results and recommendations derived are to be adopted to meet the intent of the criteria.

For occupied spaces with natural ventilation performance utilizing mechanically assisted ventilation, thermal comfort modelling shall be performed, the wind speed shall be determined from the methodology described in section 1 with the additional modelling of the mechanical assistance. The PMV shall meet the thermal comfort criteria for naturally ventilated spaces in tropical climate. Thermal comfort assessment shall be based on the PMV equation as follows:

$$PMV = a + b \times DBT + c \times WIND$$

Building Type	Value of a	Value of b	Value of c	Baseline of DBT(°C)
Industrial buildings	-4.974	0.202	-0.181	30
Healthcare facilities	-8.405	0.322	-0.686	30
Commercial atrium	-9.252	0.343	-0.747	31*
Hawker centres	-13.075	0.443	-0.460	32
Sport faciliteis	-9.945	0.379	-1.658	30
Schools	-6.805	0.267	-0.87	31
Note: The PMV value is to be rounded up to one decimal point.				

A4 GUIDANCE NOTES

The following are guidance notes to help project teams keep track of their natural ventilation design and simulation progress.

Guidelines	Description/Selection	Response & Criteria
Submission Details		Provide the project details (especially information on natural ventilated design, building massing/orientation, GFA of natural ventilated spaces, % of opening & windows, credible source of site information with surrounding buildings, vegetation and terrain, future development etc.)
Problem Statement	Objective & Work Scope	Describe natural ventilated challenges, proposed solution, desired outcome, and work scopes from the simulation model. Whenever necessary, use the architectural drawing for explanation. Describe design stages and fix simulation details. Subsequent design change has to be supported by simulation results.
Site Information	Minimum 3 times the length of the longest distance measured across the boundary of the development, or within 500 m distance from the edge of development of interest, whichever that is smaller	Describe the site information (including surrounding buildings, terrain, greenery), and illustrate how the geometrical info is incorporated into the simulation model (conversion process). Surrounding buildings within 500m distance stream wise and span wise from the edge of development of interest should be modelled explicitly; while the greenery can be modelled implicitly with tree canopy approach. Terrain effect can be ignored if elevation is less than 10m.
CFD Approach	Simulation Methodology	The CFD solver shall have the minimum capability of solving the Navier-Stokes fluid flow equations for a three-dimensional incompressible flow at steady state. Turbulence modelling shall also be included with the minimum requirement of using the standard k-ε turbulence model, coupled with standard wall

		function
	Assumption & Simplification	Describe simulation model assumption, limitations, and geometrical simplification. Whenever necessary, use the published literature data (including software manual) and comparison between architectural & CFD model for explanation
CFD Domain	Computational Domain	Describe the domain decomposition methodology; and relevant meshing type for each domain within the site. Describe the domain that be modelled implicitly with Davenport Roughness classification
CFD Meshing	Mesh size distribution and quality	To carry out proper domain decomposition. To use hexahedral cells in the rectangular domain of NV space. Tetrahedral cells can be used to model the surrounding site features of the NV space. Hybrid pyramid or cut-cell mesh can be adopted at the interface. For implicit modelling of terrain roughness effect, prismatic or hexahedral cells is recommended to be used. As a guide, the dimension of the computational mesh should be set at 0.1 to 0.2 m within the functional space of interest, 0.5 to 1.0 m for building of interest and 1.0 - 5.0 m for surrounding buildings. The computational element size in vertical direction should be set at 0.5 - 1 m from ground surface to 10m height; followed by 1 - 5m to Hmax height. Reporting on skewness and

A5 Documentation Requirement

Design Stage

The Qualified Person (QP) and the other appropriate practitioners shall ensure that the following report and building 3D model are available as evidence to demonstrate compliance with the ventilation simulation framework. The report should comprise the following items:

2.0 Cover page with a proper title, design image of development, developer's information (including developer's name and address and person-in-charge), consultant's detail (including the principal's name and authorized signature, firm's address and person-in-charge)

3.0 Table of Contents

a. Executive Summary
   i. Background of the development
   ii. Main findings
   iii. Concluding remarks

b. Background/ Introduction
   i. Building and site information
   ii. Design strategies
   iii. Detail of natural ventilation spaces (location, area, window to wall ratio etc.)

c. Methodology
   i. Describe methodology used in the study

d. Geometrical Model
   i. Isometric view of the development from various angles
   ii. Domain size used
   iii. Plan and 3D isometric model of units from various angles

e. Simulation settings
   i. Boundary conditions
   ii. CFD software/ models used/ numerical scheme
   iii. Mesh / cell sizing
   iv. Solution control-convergence criteria

f. Result and Discussions
   i. Simulation results for the development for all directions showing the main graphical plots of the plan pressure and velocity vector and salient findings
   ii. Tabulation showing the listing and details of all simulated NV spaces and the area-weighted average wind velocity within each simulated space where applicable

g. Conclusion

h. Appendix: The following plots are to be placed in the appendices:

Simulation results for the development for each direction

- Static pressure (plan view-ground & mid elevation and at the level of simulated NV space, isometric views on building façade)
- Velocity vector and contour showing the plan view at ground & mid elevation and at the level of simulated NV space, and a few isometric sectionals cut plans to show air-flow patterns across the development

Simulation results for the natural ventilated spaces for each direction

- Static pressure (plan view at the level of simulated NV space)
- Velocity vector and contour showing the plan view at the level of simulated NV space, and a few isometric sectionals cut plans to show air-flow patterns across the NV space

Verification Stage

- The project team shall declare if any changes had been made in actual built layout compared to the submitted 3D ventilation simulation model in the design stage. The re-assessment of ventilation simulation will depend on the extent of changes and their impacts on NV performance.
- If thermal comfort modelling assessment is attempted, the percentage of opt-out decisions of home buyers should be table.